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Request for grant of a patent

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1. Your reference — BB-REAR

2. Patent application number *(The Patent Office will fill in this part)* — 0227191.4 — 21 NOV 2002

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

   ADRIAN MICHAEL GRIFFITHS
   WATER SIDE,
   PRESTON BAGOT,
   HENLEY-IN-ARDEN,
   SOLIHULL.
   B95 5ED

   Patents ADP number *(if you know it)* — 7016488002

   If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention — BICYCLE WITH SUSPENSION AND INTERCONNECTION ARRANGEMENT

5. Name of your agent *(if you have one)*

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

   WATER SIDE
   PRESTON BAGOT
   HENLEY-IN-ARDEN,
   SOLIHULL.
   B95 5ED

   Patents ADP number *(if you know it)*

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
   a) any applicant named in part 3 is not an inventor, or
   b) there is an inventor who is not named as an applicant, or
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Continuation sheets of this form	0
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Claim *(s)*	0
Abstract	0
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Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature Adrian Griffiths Date 17. 11. 2002

12. Name and daytime telephone number of person to contact in the United Kingdom

ADRIAN GRIFFITHS
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Notes

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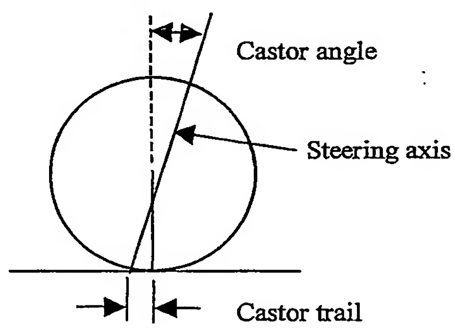
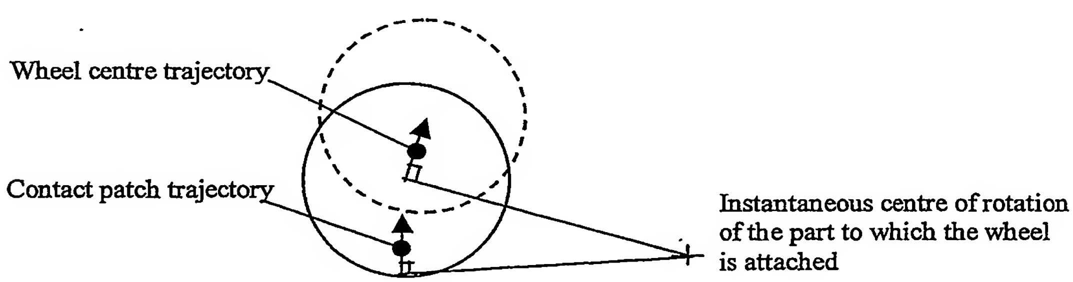
BICYCLE WITH SUSPENSION AND INTERCONNECTION ARRANGEMENT

Terminology

Anti brake dive ; A property of the front suspension which describes its ability to prevent deflection when the brakes are applied by reacting force through its linkages rather than its springs.
Anti-brake lift ; A property of the rear suspension, which describes its ability to prevent deflection when the brakes are applied by reacting force through its linkages rather than its springs
Anti-phase motion ; When the front and rear wheels both move vertically but in opposite directions.
Anti-squat ; A property of the rear suspension, which describes its ability to prevent suspension movement when a tractive load is applied by reacting force through its linkages rather than its springs.
Castor angle ; The angle to the vertical in the side view that the steering axis makes with the ground.
Castor trail ; The horizontal distance from the wheel centre to the point where the steering axis intersects with the ground in the side view.



Contact patch trajectory ; The path of the contact patch centre as seen from the side view as the suspension articulates from rebound to bump. This characteristic is closely associated with anti-brake dive (for front suspensions) and anti-brake-lift (for rear suspensions).
Contact patch trajectory angle. The angle to the horizontal of the contact patch trajectory.
In-phase motion ; When the front and rear wheels both move vertically and in the same direction.
Coupling ; When one parameter influences another, the parameters are said to be coupled.
Interconnection ; A means of connecting the front and rear suspensions in such a way that vertical motion of one influences vertical motion of the other.
Sinkage ; The deflection in the vertical direction of the rider and frame (sprung mass) due to the rider's own weight.
Wheel centre trajectory ; The path of the wheel centre as seen from the side view as the suspension articulates from rebound to bump. This characteristic is closely associated with anti-squat.
Wheel centre trajectory angle. The angle to the horizontal of the wheel centre trajectory.



Background

Although bicycles incorporating suspensions have existed almost as long as have bicycles, the 'art' of suspension design has been driven mostly by other modes of transport – cars, motor-cycles etc. The relatively recent increase in popularity of bicycles designed for off-road use has raised the level of interest in suspensions for bicycles, however, some of the design considerations that are unique to bicycles have prevented some of the developments made in the broader field from translating entirely successfully to bicycles. Namely ;

- The flexibility of the suspension must be limited to keep sinkage to an acceptable level. This is due to the need to maintain ground clearance (pedal arc to ground) when riding and to ensure that the saddle is not too high when mounting.
- Transmission of power whilst the rider is in the seated position is difficult when traversing uneven terrain. The smooth delivery of torque to the pedals is more difficult and more fatiguing when the weight of the rider is born by his/her legs.
- Bracing of arms to the handlebars is difficult when traversing uneven terrain due to the shock loads, which are transmitted through them. The natural inclination of the rider under these circumstances is to hold the handlebars relatively loosely, which has the undesirable knock on effect of transferring weight otherwise born by the arms to the saddle, which in turn heightens discomfort.
- Actuation of the suspension when the transmission torque is uneven (such as when going uphill) tends to sap energy. Most designs exhibit low levels of anti squat leading to cyclic deflection of the suspension as the transmission torque fluctuates. The energy associated with these cyclic deflections is dissipated mostly in the suspension dampers and is lost. For the same reason the flexibility of the rear suspension is practically limited by a need to avoid excitation of the primary resonant frequency by cyclic torque fluctuations, typically in the region of 120 to 200 cycles per minute (corresponding to crank rotational frequency of 60 to 100 cycles per minute i.e. one torque peak per leg per cycle).
- The requirement for stiff tyres (to keep rolling resistance low) puts greater longitudinal shock loads into the wheel and frame/rider.

It is mostly in respect of these bicycle-specific issues that the invention relates although significant advantages may be gained by its application to motorcycles or any other vehicles with chain driven rear wheels.

Brief Description of the Invention

The invention comprises

- A rear suspension and chain driven transmission arrangement that offers very high levels of anti brake lift and anti-squat and does so consistently through a large range of rear suspension movement. In respect of the rear suspension and transmission, this invention makes very specific claims and is described in detail.
- A front suspension / steering system which offers conventional features such as a steering axis inclined in the side view at a an angle of castor which intersects the ground in front of the centre of the contact patch by a distance known as the castor trail (see diagram 1). The front suspension has a high degree of anti brake dive, which can be achieved by a number of different means. This invention makes no claims regarding the specific design of the front suspension.
- Front and rear suspensions which are interconnected in such a way as to offer little resistance to anti-phase motion and somewhat more resistance to in-phase motion i.e. similar to the bogie principal and to interconnected motor vehicle suspensions as featured on the Citroen 2CV for example. Once again, this invention makes no claims regarding the specific arrangement of the interconnection means, since this is now in the public domain, however the additional claim is made that the interconnection feature is made practicable on a bicycle by the combination of front and rear suspensions described above.

Existing Technology / Prior Art

- Interconnected front and rear suspensions. E.g. Citroen 2CV, Austin Metro (see diagram 1).
- Suspensions operating on the bogie principal. E.g. Railway carriages (see diagram 2).
- High anti-brake lift / anti-squat rear suspensions – numerous examples (see diagram 3 (a) to (c))
- High anti brake dive front suspensions – numerous examples (see diagram 4 (a) to (d))

Interconnected front and rear suspensions

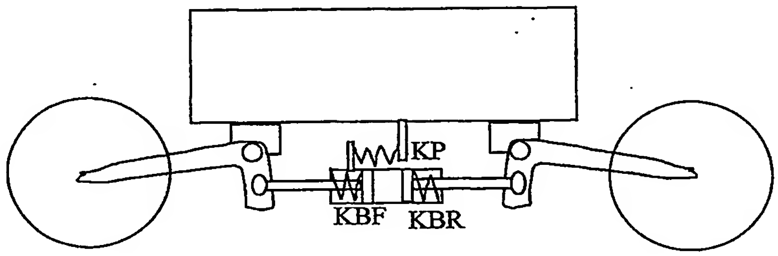


Diagram 1

The Citroen 2CV featured a mechanical interconnection means whereby the bounce frequency and the pitch frequency could be independently controlled. The front and rear bounce springs KBF and KBR were contained within a housing that was itself sprung relative to the vehicle body (spring KP). Vertical upward in-phase motion of the front and rear wheels would tend, for the most part, to result in equal and opposite compressive forces in KBF and KBR and little change in force in pitch control spring KP. Anti-phase motion would tend to transmit load to KP through load changes to KBF and KBR of opposite sign. Hence the pitch stiffness of the car could be reduced relative to the bounce stiffness. The Austin Metro achieved a similar effect using hydrogas means i.e. through displacement of fluid acting on diaphragms, which compressed a gas within the spring unit.

Suspensions operating on the bogie principal

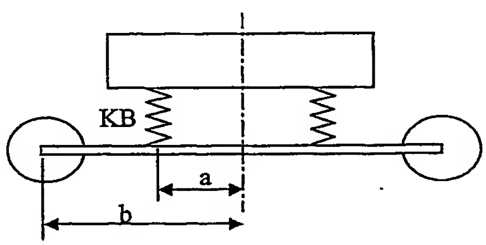
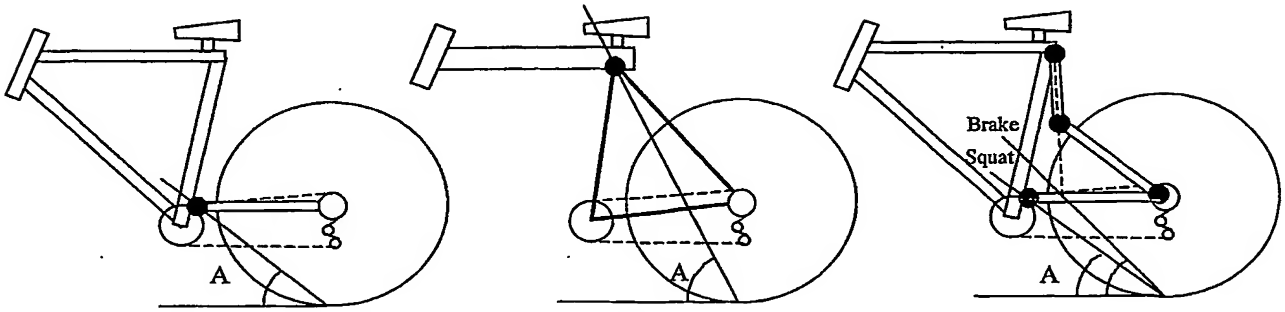


Diagram 2

Railway carriages use a similar principle of suspension. The bounce stiffness = KB per wheel, whereas the pitch stiffness is KB * $(a/b)^2$ per wheel i.e. considerably lower than the bounce stiffness.

High anti-brake lift / anti-squat rear suspensions



(a) (b) (c)

Diagram 3

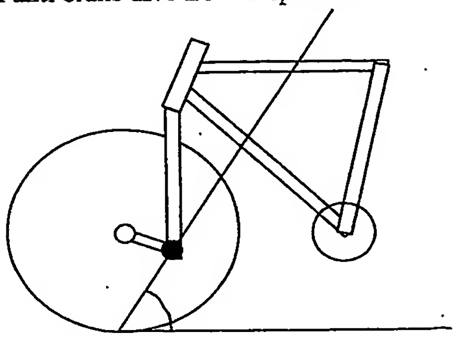
The three rear suspensions shown in figure 3 illustrate many of the contrasting characteristics that are used in contemporary designs. All three of the above are subject to patent protection (a – Renault Sport, b – Klein US6109636, c- Schulz US4997197).

The trailing arm design (a) is widely used and has a useful amount of anti-squat and anti-brake lift (angle A). The trailing arm pivot is arranged to be coincident with the point at which the chain first touches the drive gear wheel. This removes any interference or coupling between the transmission and suspension travel. If a smaller drive gear wheel is selected, however, the anti-squat angle is modified such that the line passes through the intersect point of the chain and the trailing arm i.e. rearward of the trailing arm pivot point. It can be seen that a relatively small change in chain angle arising from the selection of a different gear changes this intersect point quite markedly. This resulting increase in anti-squat comes at the expense of interference between suspension travel and the transmission, as the transmission and the suspension are no longer completely decoupled. The consequence of this lack of decoupling is that when the bicycle is ridden over a bump, the chain tension is affected, resulting in a lack of smoothness in the delivery of torque. The anti-brake lift angle is not affected by gear selection. The wheel centre trajectory is fairly vertical which tends not to be so good for absorbing sharp longitudinal inputs.

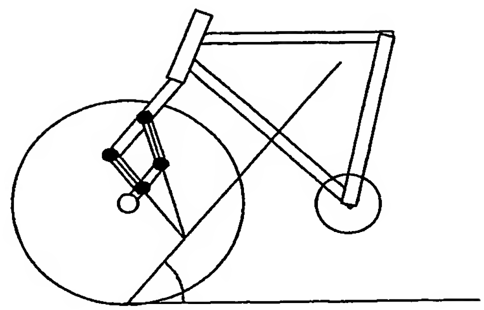
The trailing arm design (b) used by Klein Corporation exhibits very high anti squat and anti-brake lift. The transmission and the suspension are perfectly decoupled by virtue of the transmission being mounted entirely on the rear triangle. The wheel centre trajectory is around 45 degrees upwards / rearwards which is good for bump absorption. The weakest feature of this design is the lack of decoupling between the suspension and the riders feet and legs since clearly movement of the rear wheel results in longitudinal displacement of the pedals and cranks.

The third design (c) has the brakes mounted onto a part that is itself connected via a bearing to the trailing arm. This allows the anti-brake angle and the anti-squat angle to be controlled independently. In this case the high level of anti-brake lift was used to counter the inevitable pitching that would otherwise have occurred by tuning the suspension to have low stiffness for comfort reasons.

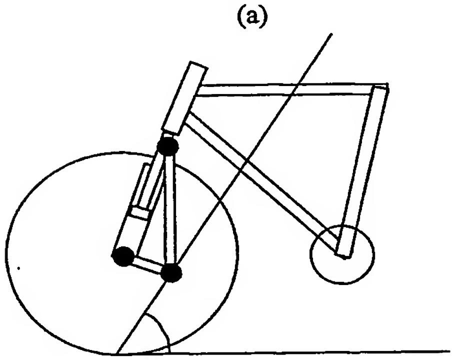
High anti brake dive front suspensions



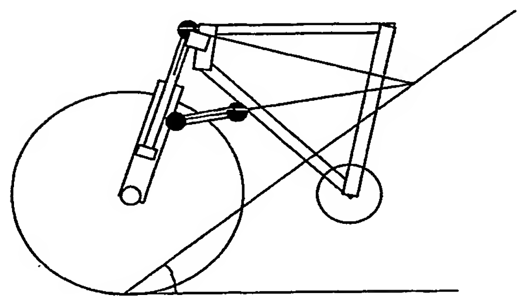
(a)



(b)



(c)



(d)

Diagram 4

The front suspensions described in diagram 4 are typical of those used in the motorcycle industry and latterly of the bicycle industry.

(a) Leading arm design used on Honda and BMW motorcycles in the 1950s.
(b) Twin link design used by NSU motorcycles in the 1940s.
(c) Conventional telescopic forks with brakes independently mounted.
(d) BMW 'Telelever' used on BMW motorcycles and mountain bikes in the 1990s.

For each of these designs, apart from (c) the brake torque is reacted by the part to which the wheel is attached.

As is seen by these examples, the field of high anti-dive front suspensions has been extensively developed over a long period of time and all except for the BMW Telelever design (d) are now available for anyone to exploit. Much of the development of front suspension forks since the 1950s has been directed at solving issues that are specific to motorcycles e.g. the drive to reduce inertia about the steering axis to reduce steering vibration. The motorcycle industry has moved on, leaving a wealth of designs that are well suited to bicycles.

(a), (b) and (c) can be arranged to give very high levels of anti-brake dive and a desirable upwards / rearwards wheel centre trajectory. The BMW design (d), by virtue of the instantaneous centre of rotation of the forks being above wheel centre height, will tend to have an upwards / forwards trajectory.

Detailed Description of the Invention

- Rear suspension and transmission
- Front suspension and interconnection means

Rear Suspension and Transmission

All the rear suspensions described in diagram 3 have shortcomings with regard to their suitability for bicycles that are softly sprung and especially for their suitability for application to interconnection where the objective of the interconnection is to lower the pitch or out of phase stiffness relative to the bounce or in phase stiffness. Generally these shortcomings are as follows ;

- Insufficient anti-squat and anti-brake lift.
- Coupling between suspension movement and chain tension.
- Coupling between suspension movement and the longitudinal position of the rider's feet.

Consequently a better solution has been devised that overcomes these issues. In essence, this requires that the chain on the tension side (i.e. between I and N in diagram 5) has a significantly higher than normal side view angle (the angle relative to the horizontal) probably, though not necessarily, of the order of 25 to 50 degrees. This would be in conjunction with a suspension arrangement that has a correspondingly high anti-squat angle A by virtue of having a high 'pole' (the point about which the rear wheel centre rotates). This 'pole' can be either real (e.g. point B in diagram 5) or virtual (point V in diagram 8) depending on the suspension type. Several embodiments are described in the following pages. It is anticipated that this suspension would have significantly lower than normal stiffness (especially in the pitch direction), one that could be expected to utilise a large amount of its available travel, accordingly the properties of anti-squat, anti-lift etc. are required to be as insensitive as possible to suspension travel. To this end, it is foreseen that the length of this stretch of chain will be approximately equal to the wheel radius in length or longer. This will correspond to the length of suspension link or links that will be required to achieve this particular aim.

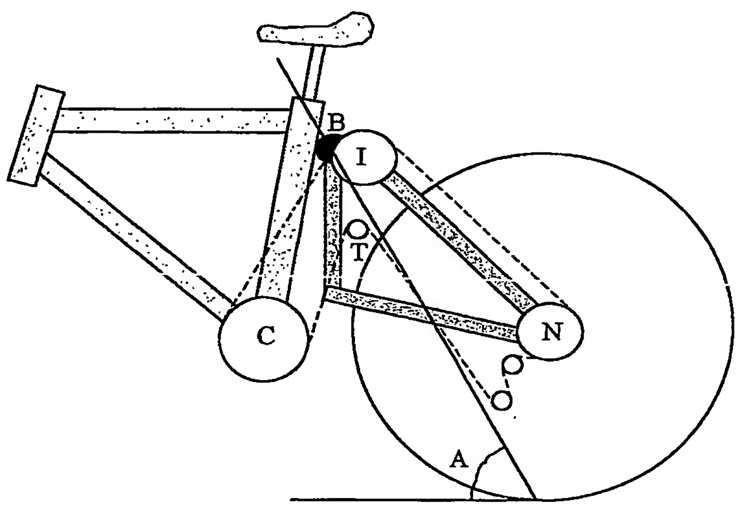


Diagram 5

Referring to diagram 5, the major features are

B = Bearing connecting the frame to the rear triangle
I = Idler gear mounted via a bearing to the rear triangle
C = Crank pulley mounted on the frame
T = Chain tensioner mounted on the frame or rear triangle
N = Nest of gears on rear wheel
A = Anti-brake lift / squat angle

The means by which the suspension is sprung is not shown and is not relevant at this point. The means of changing gear at N is shown as being a Derailleur type, though this is not necessarily so. Other types such as hub gears would be equally valid.

In the preferred case, the bearing B is arranged to lie on the line of the chain on the [illegible]on side connecting C and I in order to decouple the suspension from the transmission (i.e. such that a change in suspension position does not result in a change in chain tension). A change of gear at C or N will not result in any interference between the two (see also comments relating to configuration 3(a) regarding the influence of chain position on anti-squat).

Comparing this design with that shown in diagram 3(b), this design overcomes the problem of suspension vertical motion influencing the longitudinal position of the rider's feet. The virtues of 3(b) are retained, namely those of high anti-squat, good wheel centre trajectory and, as mentioned above, the decoupling of suspension travel from the transmission.

Other manifestations

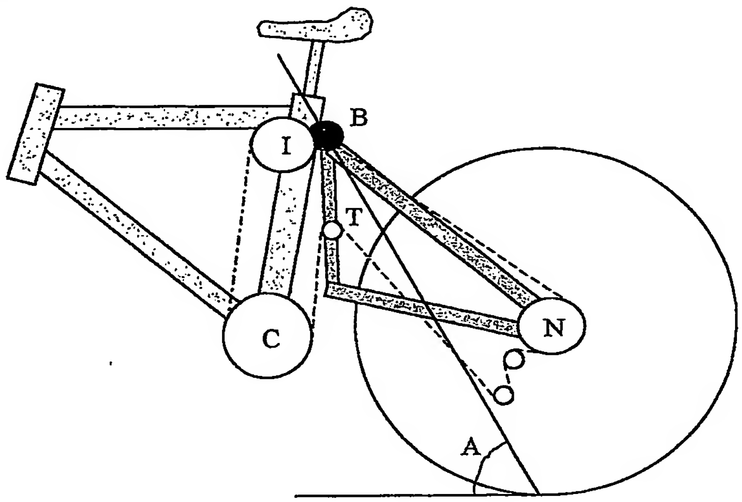


Diagram 6

Referring to diagram 6, the idler gear is mounted on the frame and, in the preferred case, the bearing B lies on the line of the chain connecting I and N. This preserves the decoupling of the suspension and the transmission.

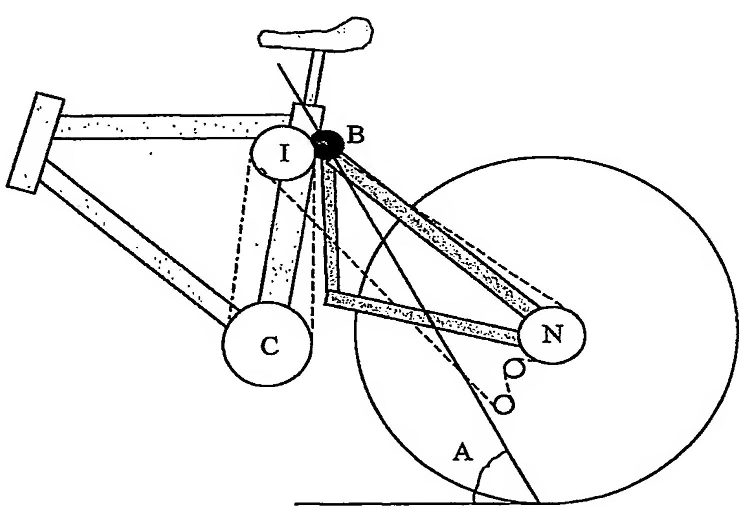


Diagram 7

This configuration is similar to that shown in diagram 6, with the idler on the frame. In this case there are two transmission chains, the first to transfer torque from the main crank C to the idler I, the second to transfer torque from the idler I to the rear nest of gears N. It is likely that with such a configuration, the two chains would need to be on opposite sides of the bicycle and that a second idler lying on the same axis and constrained to rotate at the same speed as the first would be necessary.

In a further configuration, the idler or idlers could be mounted to the rear triangle following the principles laid down in diagram 5 regarding the location of the bearing, but with two transmission chains as mentioned above.

In a another permutation of either of these where the transmission is split, the means of transmitting torque from the crank C to the idler N could be by another means such as bevel gears and drive shafts or a hydraulic means.

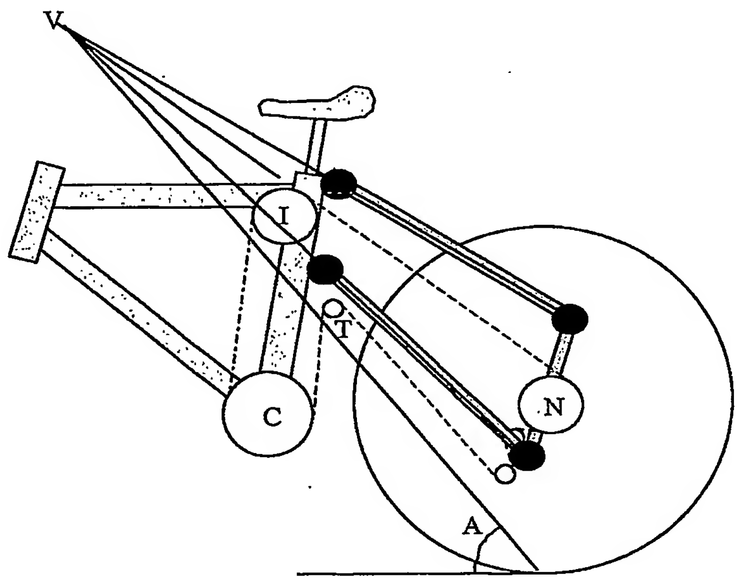


Diagram 8

Another configuration could involve substituting the rear triangle from the configuration shown in diagram 6 with a twin link arrangement whereby, preferably, the chain in tension connecting I and N is aligned with the virtual instantaneous centre of rotation (V) of the rear wheel centre. To work well, this alignment would need to be held throughout the range of suspension travel.

Permutations on this theme could involve transferring the torque from C through I to N using two chains as described previously or using some other means of transferring torque from C to I (also previously described).

Finally, it may be possible to substitute the twin link arrangement described above with some other arrangement that has a similar behaviour with regard to the virtual centre of rotation of the rear wheel and its movement with respect to suspension travel. Such an arrangement could be used in conjunction with the transmission arrangements described above (i.e. one chain with tensioner, two chains, or using another means to transmit torque from C to I in conjunction with a chain to transmit torque from I to N).

Front Suspension and Interconnection Means

To interconnect the front and rear suspensions in such a way as to offer small resistance to wheel anti-phase motion, both front and rear suspensions must have very high levels of anti-brake dive and, in the case of the rear suspension, very high anti-squat. Any of the front suspensions shown in diagram 4 could potentially be used in conjunction with the rear suspension described above to fulfil the criteria

for interconnection, indeed the front suspension need only fulfil one criterion, that [illegible]h anti-brake dive.

The interconnection means is also potentially varied in nature. The preferred design would be something like that used on the Citroen 2CV, but other means could be used to equal effect such as

- Hydraulic, pneumatic or oleo pneumatic interconnection.
- Interconnection using cranks and torsion bars

Since the means of interconnecting front and rear suspensions can safely be regarded as prior art, these various methods of interconnection will not be described in detail. By way of example, a mechanical means will be described with the purpose of demonstrating the suitability of the rear suspension for the purpose of interconnection.

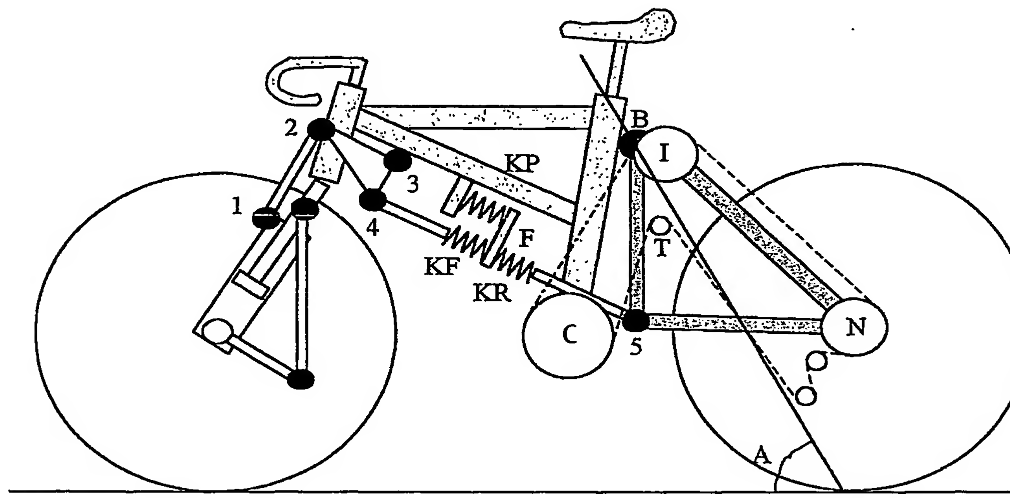


Diagram 9

Front suspension = as per diagram 4(c)
Rear suspension = as per diagram 5
Joint 1 = connection between fork body (which moves with the wheel) and link
Joint 2 = connection between link and bell crank
Joint 3 = connection between bell crank and frame
Joint 4 = connection between bell crank and interconnection
Joint 5 = connection between interconnection and rear triangle
F = Spring abutment part (constrained to slide along the frame along a line roughly parallel to a line joining 4 and 5)
KF = front bounce (in phase) spring
KR = rear bounce (in phase) spring
KP = pitch spring

Three features are particularly noteworthy

- The interconnection is in tension. The part is much easier to design for lightness as a system in tension.
- The high attachment point for the rear triangle is complementary to the aim of keeping the interconnection system in tension.
- The distance from the rear wheel centre to the rear triangle attachment point is limited practically by the size of the wheel. In order to keep the interconnection system working at a manageable ratio ((N to B) / (B to 5) the higher the ratio the higher will be the loading on all the interconnection pivot joints) there needs to be a reasonable amount of space underneath the rear triangle attachment point.

These features are consistent with the rear suspension described.

PCT Application
GB0305078